Solar Dynamics Observatory (SDO)
Goddard Dynamic Simulator (GDS)
Requirements
464-ACS-REQ-0029

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Chapter 1

Scope

This document gives the requirements for the Goddard Dynamic Simulator (GDS) systems used for build and system testing of the Solar Dynamics Observatory (SDO) Flight Software and flight hardware developed by Goddard. Testing of software not developed by Goddard is not covered, and unit testing of software is not covered.

SDO Flight Software will reside in several CPUs in the spacecraft. In general, there is an independent test environment for each CPU, as well as integrated test environments for testing one or more CPUs together. Requirements for all of these environments are given.

Mission-independent requirements for the GDS simulator are given in General Goddard Dynamic Simulator Rec (464-ACS-REQ-0028). Only additional or mission-specific requirements are given here. In particular, some of the requirements in this document merely specify the mission-specific parameter for a general requirement, and thus don't read like a requirement sentence.

The section numbering of this document follows that document, so some sections are present here even though SDO does not have the corresponding hardware.

This document gives requirements; specific pinouts or lists of signals are given in various spacecraft ICDs, which are referenced here.

Chapter 2

Introduction

SDO is a three-axis-stabilized Sun pointing observatory, in a geosynchronous orbit about the Earth. The geosynchronous orbit gives constant contact with a high-bandwidth ground station.

The instruments observe the Sun.

Major moving parts are the high-gain antenna, reaction wheels, and instrument mechanisms.

All GDS requirements on SDO trace to MRD 2.7.8.

GDS will be used to measure ACS performance with real software and hardware in the loop.

2.1 References

464-ACS-ICD-0049	Mechanical/Electrical/Thermal Interface Documentation for the Coarse Sun Sensors
464-ACS-ICD-0051	IRU ICD
464-ACS-ICD-0052	Goodrich Ithaco Reaction Wheel Assembly ICD
464-ACS-ICD-0062	Attitude Control Electronics Hardware/Software ICD
464-ACS-ICD-0074	Star Tracker Communications ICD
464-ACS-REQ-0028	General Goddard Dynamic Simulator Requirements.
464-ACS-REF-0074	DSS Systems Description User Manual
464-ACS-SPEC-0029	Coarse Sun Sensor performance specification
464-ACS-SPEC-0030	IRU performance specification
464-ACS-SPEC-0031	Star Tracker performance specification
464-ACS-SPEC-0032	Reaction Wheel performance specification
464-AIA-ICD-0011	Atmospheric Imaging Assembly (AIA) ICD
464-ELEC-SPEC-0004	SDO Electrical System Specification
464-EVE-ICD-0004	Spacecraft to EUV Variability Experiment (EVE) ICD
464-FSW-SPEC-0051	Bus Controller (BC) Flight Software (FSW) Requirements Specification
464-HMI-ICD-0002	Spacecraft to Helioseismic and Magnetic Imager (HMI) ICD
464-MECSM-SPEC-0028	High-Gain Antenna Gimbal Actuator performance spec
464-PROP-ICD-0008	Propulsion Subsystem Electrical ICD
464-PROP-SPEC-0016	Propulsion Subsystem Design Specification
464-THM-ICD-0070	Thermal System ICD

Chapter 3

Common requirements

3.1 User Interface

3.1.0-1 Requirement: mission-specific: The ground system is ASIST (Advanced Spacecraft Integration and System Test)
`http://rs733.gsfc.nasa.gov/`.

3.2 Redundancy

In general, the GDS provides interfaces for redundant flight components; see the sections for each component for further details.

One exception is the redundant ACE computers. The SDO project has decided it is too expensive to build two ACE ETUs for FLATSAT. However, since both ACEs are powered on in normal flight operations, some tests require a simulation of a second ACE.

The GDS provides a simulation of the second ACE in two ways. First, for flight components that interface to both ACEs, the GDS can act as the second ACE for that component. See the sections for each component for more detail. Second, the GDS can run the ACE flight software, acting as the second ACE on the spacecraft 1553 bus. The ACE flight software in the GDS interfaces with the GDS models rather than real flight component, providing almost complete ACE functionality.

When the GDS is running the ACE flight software, this is not considered a test of the flight software that is in the GDS; it is only a test of the flight software in the real ACE (or other real flight computers). The flight software in the GDS is not compiled for the flight computer, so it is not an adequate test environment for that software. To test the ACE flight software when it is running on the secondary ACE, the real ACE must act as the secondary ACE, while the GDS acts as the primary ACE. This means that every test that requires both ACEs must be run twice; once with the GDS as the secondary ACE, and once with the GDS as the primary ACE.

3.3 Configuration management

3.3.1 Development

no mission-specific requirements

3.3.2 Delivered systems

3.3.2-2 Requirement: mission-specific: The GDS harness shall match the loopbacks in the spacecraft harness for the propulsion system are specified in 464-PROP-ICD-0008, section 5.5.3.

3.3.3 Shared parameters

SDO is using a shared parameter database called `acstool`.

3.3.3-1 Requirement: Parameters that GDS needs that are in `acstool` shall be obtained from `acstool`.

3.4 Integration and Test

no mission-specific requirements

SDO will be running some dynamic simulations at I&T. This means that GDS must be able to stimulate or replace some sensors in some way, and monitor the commands to actuators; this is reflected in the requirements for each component. Note that some sensors are not stimulated, but are simply replaced on the 1553 bus. Also note that the actuator monitoring requirements may be on the spacecraft harness, not the GDS.

3.5 Electrical

GDS for SDO does not meet these requirements; they were established as a result of experience on SDO.

Chapter 4

Computers

There are four processors on SDO that contain Goddard-developed software, and are using the GDS for testing. Each processor is redundant. The processors are:

CDHMP Command & Data Handling Main Processor

ACE Attitude Control Electronics

PSE Power System Electronics

GCE Gimbal Control Electronics

There are other processors on SDO that contain software not developed by Goddard; the instruments, the star tracker, DSS. The GDS is not used to test the software in these processors; in some cases, the GDS provides a hardware-replacement simulation of the components containing these processors.

SDO uses 1553 for the spacecraft bus.

4.0.0-1 Requirement: *mission-specified* the SDO spacecraft bus is a 1553 bus. The GDS shall connect to the spacecraft 1553 bus, as defined in 464-ELEC-SPEC-0004, section 3.4.1.1.

4.0.0-2 Requirement: The RT addresses for simulated RTs shall be as specified in 464-FSW-ICD-0005, Appendix B.

4.1 Flight software guidelines

The GDS only provides a pure software simulation of the ACE processor.

The ACE processor runs safehold, and collects data from the AOCS components, passes commands to the AOCS components. It has a 1553 interface to the Main processor and some AOCS components, and direct hardware interfaces to other AOCS components.

4.1.0-1 Requirement: The simulator shall run the ACE processor flight software in a hardware replacement simulation of the ACE processor (requires a 1553 interface).

4.1.0-1 Trace: provide redundant ACE at FLATSAT, replace failed ACE hardware at FLATSAT

Chapter 5

Attitude and Orbit Control System components

On SDO, these are refered to as the ACS components.

5.0.0-2 Requirement: The hardware replacement simulation of the ACE processor shall be capable of simulating either ACE A or ACE B.

5.1 Coarse sun sensors

See 464-ACS-ICD-0049.

Sixteen coarse sun sensors (eight per ACE) give coarse attitude information, used in safehold. They have an analog interface to the ACE.

No stimulator for the coarse sun sensors is used; at I&T, the GDS drives test inputs to the ACE in the same way it drives the normal inputs to the ACE; that is a harnessing change only.

See 464-ACS-REQ-0028 5.1.0 for general requirements.

5.1.0-1 Requirement: A pure software hardware interface simulation of the coarse sun sensors shall be provided.

5.1.0-1 Trace: needed to run ACE flight software.

5.1.0-2 Requirement: A hardware replacement simulation of the coarse sun sensors shall be provided.

5.1.0-2 Trace: test CSS interface software and hardware; provide mission sim.

5.1.0-3 Requirement: The coarse sun sensor simulation shall meet the performance specifications given in 464-ACS-SPEC-0029.

5.1.0-3 Trace: match hardware performance.

5.1.1 Software

See 464-ACS-REQ-0028 5.1.1 for general requirements.

5.1.1-1 Requirement: The coarse sun sensor simulation model shall include Earth albedo effects.

5.1.1-2 Requirement: The coarse sun sensor simulation model shall include Earth and Moon occultation effects.

5.2 Digital sun sensors

See 464-ACS-REF-0074.

SDO has one two-axis DSS; it has a 1553 interface.

The GDS does *not* control a stimulator for the DSS.

5.2.0-1 Requirement: A hardware replacement simulation of the digital sun sensor shall be provided (requires a 1553 interface).

5.2.1 Software

See 464-ACS-REQ-0028 5.2.1 for general requirements.

5.2.1-1 Requirement: The digital sun sensor simulation model shall include Earth and Moon occultation effects.

5.2.1-2 Requirement: The Digital Sun Sensor model shall include velocity aberration.

5.2.1-3 Requirement: The Digital Sun Sensor model shall output packets on the 1553 in accordance with 464-ACS-REF-0074.

5.2.1-4 Requirement: The model shall support subaddress 14; all other subaddresses are declared illegal.

5.3 GPS

None on SDO.

5.4 Guide telescopes

See 7.1.

5.5 IRUs

See 464-ACS-ICD-0051. The vendor is Kearfott, model Tara 1T.

There are three two-axis IRUs. Each has a digital pulse stream interface to the ACE; the ACE has a counter for each.

See 464-ACS-REQ-0028 5.5.0 for general requirements.

5.5.0-1 Requirement: A pure software hardware interface simulation of the IRUs shall be provided.

5.5.0-1 Trace: needed to run the ACE flight software in the simulator.

5.5.0-2 Requirement: A hardware replacement simulation of the IRUs shall be provided; this requires a digital interface.

5.5.0-2 Trace: test IRU interface software and hardware; provide mission sim.

5.5.0-3 Requirement: An electronic stimulator for the IRUs shall be provided.

5.5.0-3 Trace: test flight IRU on spacecraft

5.5.0-4 Requirement: The IRU simulation shall meet the performance requirements in 464-ACS-SPEC-0030.

Note that the GDS baseline design runs at 20Hz, therefore is marginal for the 7.0 Hz bandwidth requirement.

5.5.1 Software

5.5.1-2 Requirement: The model algorithm shall be as specified in the HiFi block `SDOHiFi/Truth Model/Sensor Mech/IRU Mech`.

5.5.1-2 Trace: match flight hardware characteristics.

5.6 Magnetic Torquer Bars

None on SDO.

5.7 Magnetometer

None on SDO.

5.8 Reaction wheels

4 reaction wheels provide redundant attitude control. The wheel vendor is Goodrich, Ithaco Space Systems Division; model E.

The wheels have analog control interfaces, and a pulse tachometer.

At I&T, a copy of the wheel torque command is brought out to a spacecraft skin connector, where GDS reads it in the normal way; this is a harnessing requirement.

5.8.0-1 Requirement: A pure software hardware interface simulation of the reaction wheels shall be provided.

5.8.0-1 Trace: replace failed ACE at FLATSAT, develop test scripts with no hardware

5.8.0-2 Requirement: A hardware replacement simulation of the reaction wheels shall be provided. This requires analog and digital interfaces.

5.8.0-2 Trace: TDB - test reaction wheel interface software and hardware; provide mission sim.

5.8.0-3 Requirement: The hardware replacement simulation of the reaction wheels shall meet the performance specifications given in 464-ACS-SPEC-0032.

5.8.1 Software

See 464-ACS-REQ-0028 5.8.1 for general requirements.

5.8.1-2 Requirement: The reaction wheel simulation model algorithm shall be as specified in the HiFi block `SDOHiFi/Truth Model/Separate Body-Wheel Dynamics/RWA Dynamics`.

5.8.1-2 Trace: match flight hardware characteristics.

5.8.1-3 Requirement: The reaction wheel simulation shall provide tachometer sensor data to allow measurement of system momentum to +/- 0.2 Nms, at the maximum wheel operating speed of 6500 revolutions per minute.

5.8.1-3 Trace: ACS accuracy requirements, error budget.

5.9 Star Trackers

See 464-ACS-SPEC-0031, 464-ACS-ICD-0074.

Two star trackers provide attitude information. They output quaternions and status on the 1553 bus.

No stimulator for the star tracker is used; at I&T, GDS provides an additional RT address that provides simulated star tracker telemetry; the flight software bus controller tables are modified to use the simulated quaternion telemetry.

Alternately, if the real star tracker is powered off, the GDS may use the real star tracker RT.

5.9.0-1 Requirement: A hardware replacement simulation of the star trackers shall be provided; this requires a 1553 interface.

5.9.0-1 Trace: TDB - test star tracker interface software; provide mission sim.

5.9.0-2 Requirement: A static stimulator for the star trackers shall be provided.

5.9.0-2 Trace: test flight star tracker on spacecraft

5.9.1 Software

See 464-ACS-REQ-0028 5.9.1 for general requirements.

5.9.1-3 Requirement: The star tracker simulation shall add Gaussian noise to the dynamic simulator spacecraft attitude, not simulate the star tracker software.

5.9.1-3 Trace: simulator fidelity.

5.9.1-4 Requirement: The star tracker model shall include velocity aberration.

5.9.1-4 Trace: Error budget

5.9.1-5 Requirement: The star tracker model shall meet the performance specifications given in 464-ACS-SPEC-0031.

5.9.1-6 Requirement: The star tracker model shall model occultation by the Earth, Moon, or Sun.

5.9.1-7 Requirement: The star tracker model shall output packets on the 1553 in accordance with 464-ACS-ICD-0074.

5.9.1-8 Requirement: The fidelity of the model for the 1553 subaddresses shall be as follows:

9 RX reset; model - cause transition back to init mode, time to 0.

10 RX standby mode command; model; switch modes

11 RX attitude determination mode command - model; switch modes

23 RX Spacecraft velocity - full model.

17 mode code RX Time sync - full model.

30 TX Quaternion - model quaternion, rate, time, attitude status. Others user write.

10 .. 11 TX housekeeping - model time, mode status, sync status, others user write.

12 TX measured stars - raw write

13 TX reference stars - raw write

other unused (illegal)

5.9.1-9 Requirement: The model shall implement mode transitions as defined in TBD.

5.9.1-10 Requirement: The model shall provide for a failure mode where the tracker is stuck in any mode.

5.9.1-11 Requirement: The model shall allow the user to override the attitude status.

5.10 Propulsion

See 464-PROP-SPEC-0016, especially section 4.5.

8 bi-propellent thrusters provide attitude and orbit control. Thruster fuel and oxidizer are stored in two pressurized tanks. 10 pressure transducers monitor pressure in the system. There are 8 low pressure isolation valves, 2 high pressure isolation valves. 10 pyro valves provide additional control.

One main thruster provides the initial orbit boost from LEO to geosync. It has different thruster loads than the attitude thrusters.

There are no requirements to model heaters.

At I&T, there is a spacecraft skin connector that allows the GDS to connect to the ACE propulsion interface in the normal way. See 464-PROP-ICD-0008, section 5.5.3.

5.10.0-1 Requirement: A pure software hardware interface simulation of the propulsion subsystem shall be provided.

5.10.0-1 Trace: needed to run ACE flight software.

5.10.0-2 Requirement: A hardware replacement simulation of the propulsion subsystem shall be provided. This requires analog and digital signals.

5.10.0-2 Trace: test propulsion interface software and hardware; provide mission sim.

5.10.1 Software

See 464-ACS-REQ-0028 5.10.1 for general requirements.

5.10.1-12 Requirement: mission-specific: glitches exceed 5 microseconds for non-thruster valves, 500 microseconds for thruster valves, and 2.5 volts.

5.10.1-13 Requirement: mission-specific: Valid signals exceed 5 microseconds, 19.9 volts for the main engine, 20.0 volts for other thrusters, 20.4 volts for latch valves.

5.10.2 Hardware loads

5.10.2-1 Requirement: mission-specific: impedance 50 kohm, voltage range -10 VDC .. +40 VDC.

5.10.2-7 Requirement: mission-specific: Cable length: 7.5 meter.

5.10.2-8 Requirement: mission-specific: The loads shall be mounted in the GDS rack. Cable length: 30 feet outside thermal vacuum chamber, 70 feet inside.

5.10.3 Telemetered Monitors

5.10.3-2 Requirement: mission-specific: 2.5 volts, duration 5 uSec.

5.10.3-3 Requirement: mission-specific: (non-thruster) 20.4 volts.

5.10.3-4 Requirement: mission-specific: (thruster) 19.9 volts main engine, 20.0 volts other thrusters.

5.10.3-5 Requirement: mission-specific: timer resolution 1 uSec, accuracy 60 ppm.

5.10.3-6 Requirement: mission-specific: (isolation) 20.4 volts.

5.10.4 I&T

no mission-specific requirements

Chapter 6

Other components

6.1 Battery

6.1.0-1 Requirement: A low fidelity simulation of the battery shall not be provided; the high fidelity simulator will be used as needed.

6.2 High Gain Antenna

See 464-MECSM-SPEC-0028.

The motors driving the gimbals have a direct connection to the GCE processor, defined in 464-MECSM-REF-0140 (GIC ICD) and 464-MECSM-REF-0141 (encoder patterns).

6.2.0-1 Requirement: A hardware replacement simulation of the gimbals shall be provided.

6.2.0-1 Trace: test GCE hardware and software.

6.2.1 Software

See 464-ACS-REQ-0028 6.2.1 for general requirements.

6.2.1-1 Requirement: The HGA simulation shall model the change in spacecraft inertia due to HGA motion.

6.2.1-2 Requirement: The HGA simulation shall model the wrench on the spacecraft due to HGA motion.

6.2.1-3 Requirement: The GDS shall not communicate with the RF link simulator.

6.2.1-4 Requirement: The GDS shall assume linear motor and gear chain (no calibration required).

6.3 Power Control Electronics (PCE)

On SDO, this is called the Power System Electronics (PSE).

See 464-ACS-REQ-0028 6.3.0 for general requirements.

6.3.0-1 Requirement: Refer to the wirelist drawings for each GDS configuration to determine the power supply lines that are monitored.

6.4 Solar panels

The solar panels are fixed in relation to the spacecraft; no solar array rotation mechanism model needed.

See 464-ACS-REQ-0028 6.4.0 for general requirements.

6.4.1 Software

The GDS does not provide a low-fidelity simulation of the solar array power system; the high-fidelity model is borrowed as needed.

The GDS does not model solar panel flexible modes.

The GDS does model the position of the solar panels, and the torques and mass distribution.

6.5 Thermistors

There is no requirement for any thermal model to drive the thermistors; all thermistor temperatures are set directly by the users.

See 464-ACS-REQ-0028 6.5.0 for general requirements.

6.5.0-1 Requirement: A hardware replacement simulation of the thermistors shall be provided. This requires analog signals. The list of thermistors to be simulated is given in 464-THM-ICD-0070; refer to the wirelist drawings for each GDS configuration to determine the thermistors that are simulated in each configuration.

6.5.0-2 Requirement: A pure software hardware interface simulation of the thermistors connected to the ACE shall be provided.

6.5.0-2 Trace: required to run the ACE flight software.

Chapter 7

Instruments

The SDO instruments are AIA, EVE, HMI.

Some of the instruments have image stabilization system mirrors, that are moving during science observations. This motion induces torques on the spacecraft, which affect the pointing stability. The motion of the mirrors is essentially only in response to noise, which only affects performance, not behavior, so the GDS does not model these motions.

There are also other moving parts in the instruments; shutters, filters, etc. For any given telescope, these are not moving during science observations. However, the telescopes may not be in science mode all at the same time, and thus some may be moving these parts while others are taking data. They do not change the spacecraft moment of inertia significantly, so we still model them as noise.

7.1 AIA

The AIA instrument (see 464-AIA-ICD-0011) has four guide telescopes, some of which will be used by the ACS for fine guidance. AIA will send messages containing guide telescope data to the ACS via the 1553 bus.

For integration and test, the guide telescope vendor will provide a stimulus telescope, that puts a sun-like image in the field of view of the guide telescope. The GDS is *not* required to run the stimulus telescope.

7.1.0-1 Requirement: A hardware replacement simulation of the AIA Guide Telescope shall be provided (requires a 1553 interface).

7.1.0-2 Requirement: The guide telescope model shall include velocity aberration.

7.1.1 Software

7.1.1-1 Requirement: The 1553 packet generated by the guide telescope model shall be formatted as specified in 464-AIA-ICD-0011, section 8.7. Note table 8.7-1, and AIA_REQ_8.7.3.3 in table 8.9.1.

7.1.1-2 Requirement: The guide telescope model shall allow testing the ACS use of the guide telescope input.

7.1.1-3 Requirement: The guide telescope model shall include Earth and Moon occultation effects.

7.1.1-4 Requirement: The guide telescope noise model shall be a single Gaussian standard deviation.

7.1.1-5 Requirement: The guide telescope model shall include velocity aberration.

7.2 EVE

See 464-EVE-ICD-0004.

7.2.1 Software

7.3 HMI

HMI (see 464-HMI-ICD-0002) will send messages to the ACS via the 1553 bus; the ACS does not use the data in the message, it is just copied to the ground. Therefore the GDS does not need to set the data in these messages from models.

7.3.0-1 Requirement: A hardware replacement simulation of the HMI shall be provided (requires a 1553 interface).

7.3.1 Software

7.3.1-1 Requirement: The 1553 packet generated by the HMI model shall be formatted as specified in 464-HMI-ICD-0002, section 8.7.1.

7.3.1-2 Requirement: The GDS shall allow users to set each data point in the HMI 1553 packet.

Chapter 8

Dynamic integrator

See 464-ACS-REQ-0028 8.0.1 for general requirements.

8.0.1-2 Requirement: mission-specific: wrench sources are:

1. Sun gravity force (spherical model).
2. Moon gravity force (spherical model).
3. Earth gravity force (spherical model), and gravity gradient torque.
4. Earth atmosphere drag (in early mission phases).
5. Solar Radiation wrench.
6. Propulsion
7. Reaction Wheels
8. High Gain Antenna
9. Magnetic fields; Spacecraft dipole in Earth dipole.

A spherical gravity model is accurate enough for the GDS; we are not predicting actual orbits, just verifying software functionality.

The magnetic field model is for modeling the torque due to the net spacecraft magnetic dipole moment in the Earth magetic field. Since SDO is normally in a geosync orbit, a dipole model of the Earth magnetic field is accurate enough.

The following effects are *not* modeled. The SDO GN&C team has determined these effects are not significant enough to require detailed models; they are adequately modeled as simple noise.

1. Fuel slosh.
2. Flexible body modes (including solar panels).
3. Instrument moving parts.

8.0.1-3 Requirement: mission-specific: cycle time is 0.040 seconds.

8.0.1-3 Trace: 464-ACS-ICD-0062 states minimum thruster pulses are approximately 0.050 seconds; the actual minimum is about 48 milliseconds. GDS cycle must be shorter than that. It must also evenly divide one second.

8.0.1-4 Requirement: mission-specific: integration step size is 0.050 seconds.

8.0.1-4 Trace: same as cycle time

8.0.1-5 Requirement: mission-specific: spacecraft time is distributed on the 1553 bus; see 464-CDH-ICD-0057 (SDO time distribution specification).

Chapter 9

Other

9.1 ACE arbitration

The ACE arbitration signals allow one ACE to tell whether the other is healthy.

When GDS is running a pure software ACE, the ACE software drives the ACE arbitration signals.

When GDS is used to test a stand-alone ACE, an arbitration model drives the arbitration signals.

9.1.0-1 Requirement: The ACE arbitration model shall drive the ACE arbitration signals in accordance with 464-SYS-CORR-0035.

9.1.0-2 Requirement: The ACE arbitration model shall provide for failure modes that include forcing either wire to static one or zero.